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COMPARING RECENT ASSET PRICING MODELS: Evidence from Tokyo Stock Exchange Firms

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Summary

In this paper, I test five recent asset pricing models and investigate which one explains well the data for Japan. I conduct standard cross-section asset pricing tests on Japanese data to examine the explanatory power of each asset pricing model. The Fama-MacBeth Regression test (Fama and MacBeth 1973), Generalized Method of Moments (GMM) test with Hansen-Jagannathan distance measure (Hansen and Jagannathan 1997) and Gibbons–Ross–Shaken (GRS) test (Gibbons et al. 1989) are conducted on the whole sample period from January 1978 to December 2018 and also on three sub-period, with phase 1: from the starting point to December 1989; Phase 2: from January 1990 to December 2009; Phase 3: from January 2010 to December 2018. I test recent asset pricing models and investigate which one of the five candidate models explains well the data for Japan.

The test results show that for the entire sample period, the conservative-minus-aggressive (CMA) factors are not significant, which is consistent with the conclusion in Fama and French (2017), that CMA is a redundant factor for Japan. Moreover, all candidate models are rejected by Gibbons-Ross-Shanken test (GRS test). The test results show that the Fama-French five-factor model with UMD does a better job in explaining the Japanese market than other candidate models. For phase 1, UMD is a redundant factor and it is difficult to conclude that which candidate model did better since the adjusted R-squared values and the HJ-distance measures show little difference between each candidate models. For phase 2, CMA, SMB and the empirical q factors are redundant factors. Overall, the six-factor model and the original five-factor model have stronger explanatory power. For Phase 3,

the five-factor model and the empirical q-factor model seem to do a better job in explaining Japanese market. SMB, HML and RMW in the five-factor model are strong explanatory variables. Also, RMV and ROP in the empirical q-factor model also show strong explanatory power. UMD and CMA are redundant factors.

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1. Introduction

After discovering the inadequate explanatory power of the conventional Capital Asset Pricing Model, many sought to create new models to explain the market by expanding the CAPM model introduced by Sharpe (1964) and Lintner (1965). The traditional asset pricing model uses only one variable to describe stock returns, and multi-factor models are usually extensions of CAPM (Sharpe 1964, Lintner 1965). In Section 2, I will discuss briefly about CAPM, Fama and French (1993)'s three-factor model, Fama-French (2015)'s five-factor model, Carhart (1997) 4-factor and the empirical *q*-factor model proposed by Hou, Xue and Zhang (2015).

In the term-paper of Seminar on Portfolio Management in 2018, our group have investigated the behavior of Fama and French (2015) five-factor asset pricing model by using Japanese data. Based on the results from Fama-MacBeth regression analysis on my test portfolios, we came to a conclusion that CMA factor probably does not have explanatory power for Japanese market. This conclusion is consistent with those in Fama and French (2017), that CMA factor is a redundant factor for Europe and Japan. GMM tests with Hansen-Jagannathan-distances measure were also conducted. By comparing Hansen-Jagannathan-distances of several candidate asset pricing models, we found that the model dropping CMA factor has the smallest figure and thus it has the least pricing error. Overall, we can conclude that the Fama and French five-factor model cannot be an appropriate pricing model for Japanese data. The Portfolio Management seminar brought out my interest in whether other different asset pricing models are also having trouble in explaining Japanese market data.

The main purpose of this paper is to determine whether recent asset pricing models could explain the stock return data from Japan well or not. I test Fama and French (1993) three-factor model, Fama and French (2015) five-factor model, Fama and French (2015) five-factor model with the Carhart (1997) momentum factor (Up-Minus-Down, UMD), the Carhart (1997) four-factor model, and the empirical *q*-factor model proposed by Hou et al. (2015)

The Section 2 briefly explains CAPM (Sharpe 1964, Lintner 1965), Fama and French (1993) three-factor model, Fama and French (2015) five-factor model, the Carhart (1997) four-factor model, and empirical *q*-factor model proposed by Hou et al. (2015). Section 3 describes the methodology and the data. Section 4 discusses the empirical results I obtained in this study. Section 5 is robustness checks in which I performed asset pricing tests on the sub-period data, and Section 6 concludes the paper.

2. Literature Review

2.1. CAPM (Sharpe, 1964)

Since risk and uncertainty upon asset prices will always exist, economists developed a model that help calculate expected return and the risks for investors. The CAPM model introduced by Sharpe (1964) and Lintner (1965) is based on the earlier work of Markowitz (1959), who devised the modern portfolio theory. Modern portfolio theory suggests that investors could mitigate or even remove specific risk by diversifying a portfolio. However, the problem of systematic risk, the market risk, could not be solved through diversification. Later, Sharpe (1964) and Lintner (1965) built on Markowitz's work to develop CAPM by assuming the existence of lending and borrowing at a risk-free rate of interest. This equation includes the relationship between risk and expected return. The basic CAPM could be written as follows.

$$E(R_i) = R_f + \beta_i\big(E(R_m) - R_f\big) \tag{1}$$

In equation (1), $E(R_i)$ is the expected return on the capital asset; R_f is the risk-free rate of interest; $E(R_m)$ is the expected return of the market; $E(R_m) - R_f$ is the equity market premium; and β_i is the beta of the security. Beta measures a stock's relative volatility, which is the fluctuations of the price of a particular stock comparing with the fluctuations of the entire stock market. Although many later studies raise doubts about the validity of CAPM, this model is widely used, and it provides the basis to many multi-factor asset pricing models.

2.2. Fama and French Three-Factor Model (Fama and French, 1993)

The Fama and French (1993) three-factor model is a multi-factor asset pricing model developed on the basis of the CAPM by adding a size risk factor and a value risk factor to the market risk factor. Fama and French (1993) claim that the cross-section of average returns on U.S. common stocks show little relation to the market beta of CAPM. After comparing the explanatory power of candidate variables and market β, they find that in combinations, size and book-to-market equity can explain the cross-section of average returns on U.S. common stocks well. The basic Fama and French three-factor model could be written as follows.

$$r_{ji} - r_{ft} = \beta_i^M (r_{Mt} - r_{ft}) + \beta_i^{SMB} SMB_t + \beta_i^{HML} HML_t + \varepsilon_{jt} \tag{2}$$

In equation (2) r_{ji} is the total return of the portfolio in month t; r_{ft} is the risk-free rate return at t; $r_{ji} - r_{ft}$ is the expected excess return; r_{Mt} is the total market portfolio return; $r_{Mt} - r_{ft}$ is the excess return on the market portfolio; SMB_t is the size premium; and HML_t is the value premium; and $\varepsilon_{jt}$is the error term. SMB (Small-Minus-Big) is the difference between the returns on small-stock portfolios and big-stock portfolios with the same weighted-average book-to-market equity. In this way, the difference could mitigate the influence of book-to-market equity. Similarly, in the HML (High-Minus-Low), the two components are returns on high book-to-market equity and low book-to-market equity with the same weighted-average size. Thus, the difference of these two components could mitigate the size effect.

2.3. Carhart Four-Factor Model (Carhart, 1997)

By adding an additional momentum factor to the Fama and French (1993) three-factor model, Carhart (1997) developed a four-factor asset pricing model that could explain persistence in equity mutual fund's mean and risk-adjusted returns, according to the paper, almost completely. Momentum of stocks is the tendency for the stock price to continue rising if it is going upwards, and to continue decreasing if it is going downwards. The basic Carhart four-factor model could be written as follows.

$$r_{ji} - r_{ft} = \beta_i^M (r_{Mt} - r_{ft}) + \beta_i^{SMB} SMB_t + \beta_i^{HML} HML_t + \beta_i^{UMD} UMD_t + \varepsilon_{jt} \tag{3}$$

In equation (3), all the other parts are same as in the Fama and French three-factor model, except for the UMD (Up-Minus-Down) factor, which is the one-year momentum in stock returns.

2.4. Fama and French Five-Factor Model (Fama and French, 2015)

While there are many evidences suggest that the three-factor model can explain the cross-section variation of stock returns in U.S. and in some other countries, there is still profitability and investment related variation left unexplained by the Fama and French (1993) three-model. Fama and French (2015) extended their three-factor model by adding profitability and investment factors to the market, size, and value factors. Although tests results in Fama and French (2015) show that after adding the additional profitability and investment factors, the value factor becomes redundant, there is still adequate explanatory power in the five-factor model. The basic Fama and French five-factor model could be written as follows.

$$r_{ji} - r_{ft} = \beta_i^M (r_{Mt} - r_{ft}) + \beta_i^{SMB} SMB_t + \beta_i^{HML} HML_t + \beta_i^{RMW} RMW_t + \beta_i^{CMA} CMA_t + \varepsilon_{jt} \tag{4}$$

In equation (4), with other parts remaining the same as the Fama and French three-factor model, the additional RMW (Robust-Minus-Weak) profitability factor is the difference between the returns on diversified portfolios of stocks with robust and weak profitability and CMA (Conservative-Minus-Aggressive) investment factor is the difference between the returns on diversified portfolios of the stocks of low and high investment firms.

2.5. Empirical *q*-Factor Model (Hou, Xue and Zhang, 2015)

The same year when Fama and French (2015) proposed the five-factor model, Hou, Xue, and Zhang (2015) proposed a four-factor model that includes the market factor, a size factor, and investment factor, and a profitability factor. This model is built on the neoclassical q-theory of investment, and in some degree, inspired by investment-based asset pricing. They claim that after a comprehensive examination of nearly 80 anomalies, evidences suggest that their empirical q-factor model is better in explaining the market because Fama and French (1993) three-factor model failed to capture most of the anomalies. The basic empirical q-factor model could be written as follows.

$$E[r^i] - r^f = \beta^i_{MKT} E[MKT] + \beta^i_{ME} E[r_{ME}] + \beta^i_{\frac{I}{A}} E\left[r_{\frac{I}{A}}\right] + \beta^i_{ROE} E[r_{ROE}] \tag{5}$$

In equation (5), $E[r^i] - r^f$ is the expected return of an asset in excess of the risk-free rate; MKT is the market excess return; r_{ME} is the difference between the return on a portfolio of small size stocks and the return on a portfolio of big size stocks; $r_{\frac{I}{A}}$ is the difference between the return on a portfolio of low investment stocks and the return on a portfolio of high investment stocks; r_{ROE} is the difference between the return on a portfolio of high profitability (ROE, return on equity) stocks and the return on a portfolio of low profitability stocks. $E[MKT]$, $E[r_{ME}]$, $E\left[r_{\frac{I}{A}}\right]$, and $E[r_{ROE}]$ are the expected factor premiums and β^i_{MKT}, β^i_{ME}, $\beta^i_{\frac{I}{A}}$, β^i_{ROE} are the factor loadings on each of the four factors.

3. Methodology and Data

This paper examines the monthly data of shares listed on Tokyo Stock Exchange (TSE). The primary data sources for financial statement data is NIKKEI NEEDS FinancialQuest, and the market attributed data such as market value of equity and individual stock return is from NIKKEI NEEDS Daily Stock Return Database. More than 90% of the firms listed on the TSE have fiscal year-end at the end of March. Therefore, sample firms are sorted at the end of August in each year. The observation period is from January 1978 to December 2018.

For comparative purposes, I divided the whole observation period into three characteristic sub-periods. The first subperiod is from the starting point, January 1978, to December 1989. During this period, there was a stock market bubble in Japan. Stock market prices and real estate inflated rapidly. In December 1989, the stock market bubble burst. This subperiod includes the economic bubble period. The second subperiod is from January 1990 to December 2009. During this period, the economic stagnation in Japan was serious after the bubble burst, which brought huge influence on Japanese economy. This subperiod includes the period known as the Lost two decades. The third subperiod starts from January 2010 to December 2018. In January 4, 2010, the new trading system *arrowhead* was launched. This period includes the time Japan entered the High Frequency Trading era.

3.1. Risk Factors and Test Portfolios Construction

For risk factors, the definitions are almost the same as the definitions of the nine factors in Kubota and Takehara (2018), Carhart (1997), and Hou et al. (2015), except for the ROE factor by Hou et al. (2015). In this paper, RMV represents the size factor, RIA represents the investment factor, and the ROP represents the profitability factor in the empirical q-factor model. I construct three sets of portfolios for asset pricing tests. The sorting method of each portfolio is different. The proxy for the risk-free rate is overnight call money rate with collateral.

For the first set of portfolios is 18 portfolios (P18), investment-to-assets (I/A) is measured as the annual change in total assets divided by 1-year-lagged total assets. Size is the market equity. For the profitability factor ROE, I use realized ROE in the empirical q-factor model for analysis. In order to compute the forecast ROE factor, as in the Hou et al. (2015), the operating profit data is necessary. However, the operating profit is not available in the financial statement disclosed by Japanese firms. Therefore, realized ROE (6) is computed instead of the forecast ROE.

$$Realized\ ROE = \frac{Ordinary\ Profit}{BV_{t-1}} \text{ (Ordinary profit: Keijo-Rieki)} \tag{6}$$

I employ the methodology of Hou et al. (2015), in which, at the end of August of each year t, stocks are split into 2 groups by using median TSE size. Then, I break stocks into 3 I/A groups at the end of August of year t, using the TSE breakpoints at the end of the fiscal year $t-1$ for the low 30%, middle 40%, and high 30% of the ranked values of I/A. Finally, I sort stocks into 3 groups according to the TSE breakpoints for the low 30%, middle 40%, and high 30% of the ranked values of ROE in the start of each month. All three sorts are done independently. By taking the intersections of the 2 size groups, 3 I/A groups, and 3 ROE groups, I formed P18 (2-by-3-by-3), a set of portfolio sort on size (RMV), I/A (RIA), and ROE (ROP).

For the second set of portfolios is 20 portfolios (P20), I employ the methodology of Takehara (2019) with an adjustment. I removed the momentum ranked quintile portfolios in the original methodology. At the end of June in each year t, I break stocks into 5 groups using TSE quintile distribution of the ranked values of MVE (market value of equity). Five B/M-ranked portfolios, five ROE-ranked portfolios, and five GTA (growth rate of total asset)-ranked portfolios are conducted in a similar way independently. In total, P20 has 20 portfolios sort on MVE (5), B/M (5), ROE (5), and GTA (5) independently.

For the third set of portfolios is 45 portfolios (P45), I employ the same methodology of Kubota and Takehara (2018). For Japanese data, I used current earnings divided by the end book value of equity to compute variable “OP” (operating profitability). I used change in the book value of total assets of the previous period divided by end book value of total assets of year $t-1$ to compute variable “INV” (measure of asset growth). I constructed size and B/M-ranked 15 (3×5) portfolios, size and OP-ranked 15 (3×5) portfolios, and size and INV-ranked 15 (3×5) portfolios. In total, the third set of portfolios P45 is consisted of 45 portfolios.

3.2. Summary Statistics

Table 1 reports the basic descriptive statistics of the risk factors used in this paper. The observation period is from January 1978 to December 2018. For the excess market return, MKT, the average monthly return is 0.347%, reported in percentages. The only negative factor return is the momentum factor, UMD, which is -0.041%. In the standard deviation column, MKT shows the highest variability. The last three columns are the 25th percentile, the median, and the 75th percentile. All the factor returns have positive number in the median column. The difference between the mean and the median is substantial for UMD.

Table 1. Descriptive statistics of each factor (01/1978–12/2018)

Factors	**Mean**	**S.D**	**25%ile**	**Median**	**75%ile**
MKT	0.347	5.093	-2.275	0.491	3.469
SMB	0.130	3.332	-1.738	0.118	2.276
HML	0.473	2.906	-1.242	0.366	1.988
RMW	0.029	2.274	-1.260	0.006	1.253
CMA	0.088	2.357	-1.086	0.128	1.337
UMD	-0.041	4.465	-2.045	0.448	2.461
RMV	0.173	3.306	-1.511	0.194	1.982
RIA	0.177	2.058	-1.042	0.067	1.364
ROP	0.087	2.014	-1.032	0.015	1.241

MKT, excess returns from the value-weighted market index; SMB, small-minus-big factor; HML, high-minus-low factor; RMW, robust-minus-weak factor; CMA, conservative-minus-aggressive factor; UMD, up-minus-down factor; RMV, size factor; RIA, investment factor; ROP, profitability factor. “Mean” is an arithmetic average of monthly return from factors (in %). “S. D” is a standard deviation of risk factors. “25%ile,”, “median,” and “75%ile” denote the 25 percentile, median, and 75 percentile of risk factors, respectively.

I also computed descriptive statistics of the risk factors in three subperiod. In **Table A1 (Appendix)**, which is the descriptive statistics for the first subperiod, the market excess return, MKT, has an average monthly return of 1.132%. This number corresponds with the economic bubble, during which, the stock prices inflated greatly. All factor returns are positive in the mean column. In the standard deviation column, UMD factor shows the highest variability. In the median column, the only negative factor return is RIA, which is -0.063%. The differences between the mean and the median are not substantial, however, UMD factor has the biggest difference. In **Table A2**, which is the descriptive statistics for the second subperiod, the market excess return, MKT has a negative monthly return at -0.323% and it has the highest variability. Most of the average factor returns are negative except for HML, CMA, RMV, and RIA. The difference between the mean and the median is substantial for UMD factor. In **Table A3**, which is the descriptive statistics for the third subperiod, the market excess return, MKT, has an average monthly return of 0.788%. The only negative factor return is CMA, which is -0.118%. In this subperiod, the differences between the mean and the median are not substantial. In summary, MKT factor tends to increase after the recovery from economic bubble and stagnation; SMB factor recovered from the economic stagnation; HML factor decreased greatly since the second Subperiod; RMW factor recovered from the economic stagnation as well; CMA factor tends to decrease over time; UMD factor barely recovered to a positive number; RMV factor also recovered; RIA factor tends to decrease over time; and ROP factor recovered to a positive number.

Table 2 reports the correlation numbers among risk factors. The observation period is from January 1978 to December 2018. I find that ROP and RMW has the highest correlation at 0.943. However, this is because these two factors have similar definition. Similarly, RIA and CMA has a correlation of 0.705 because of the asset growth effect. Excluding these two pairs of risk factors, HML is correlated with RMW at -0.416 and UMD at -0.345; CMA is highly correlated with HML at 0.430 and with RMW at -0.497. Correlation numbers among risk factors are also computed for three subperiod.

Table 2. Correlation matrix of factors (01/1978–12/2018)

	MKT	SMB	HML	RMW	CMA	UMD	RMV	RIA	ROP
MKT	1.000	-0.094	-0.167	-0.024	-0.243	-0.133	-0.133	0.002	-0.054
SMB	0.219	1.000	0.096	-0.265	0.009	-0.170	0.937	0.114	-0.263
HML	0.000	0.394	1.000	-0.416	0.430	-0.345	0.319	0.338	-0.344
RMW	0.488	0.000	0.000	1.000	-0.497	0.225	-0.264	-0.404	0.943
CMA	0.000	0.280	0.000	0.000	1.000	-0.076	0.069	0.705	-0.305
UMD	0.108	0.063	0.000	0.000	0.097	1.000	-0.228	-0.073	0.222
RMV	0.033	0.000	0.000	0.000	0.971	0.020	1.000	0.153	-0.257
RIA	0.573	0.019	0.000	0.000	0.000	0.241	0.016	1.000	-0.144
ROP	0.198	0.000	0.000	0.000	0.000	0.000	0.000	0.002	1.000

Pearson correlations among the nine factors are shown in the upper-right triangular part of the matrix, and Spearman rank correlations are shown in the lower-left triangular part.

Table A4 and A5 reports correlation among risk factors for the first and second subperiod. In **Table A6**, which is the correlation among factors in the third subperiod, RMV and SMB have the highest correlation at 0.929; SMB is correlated with MKT at -0.336 and HML at -0.406; HML is correlated with MKT at 0.320 and RMW at -0.544; CMA is correlated with HML at 0.450 and CMA at -0.483; UMD is correlated with SMB at 0.413, HML at -0.558, and RMW at 0.334.

4. Empirical Results

Standard cross-section asset pricing tests are conducted to test the explanatory power of the asset pricing models I mentioned in Section 2. Generalized Method of Moments (GMM) test with Hansen-Jagannathan distance measure (Hansen & Jagannathan 1997) and Gibbons–Ross–Shaken (GRS) test (Gibbons et al. 1989) are also conducted.

4.1 Fama-MacBeth Regression (1973)

Fama and MacBeth (1973) test the relationship between average return and risks. They state that theoretical basis of this method, which is known as Fama-MacBeth Regression, is the "two-parameter" portfolio model and models of market equilibrium derived from the two-parameter portfolio model. Fama-MacBeth Regression estimates the beta and risk premium for each risk factor that is expected to determine asset prices. The following multi-beta model (7) is one of the models that I conducted Fama-MacBeth Regression test on. The following Table 3, 4, and 5 report the overall fitness of each model and the significance level of each factor for P18, P20, and P40. The observation period of test portfolios is from January 1978 to December 2018.

$$r_j - r_f = \gamma_0 + \gamma_1\beta_j^{MKT} + \gamma_2\beta_j^{SMB} + \gamma_3\beta_j^{HML} + \gamma_4\beta_j^{RMW} + \gamma_5\beta_j^{CMA} + \varepsilon_j \tag{7}$$

Table 3. Fama and MacBeth Regression Test Result for Test Portfolio P18 (01/1978–12/2018)

	Three-factor model	Five-factor model		Five-factor + UMD		Carhart 4-factor model		q-factor model	
Intercept	0.437	-0.257		-0.078		-0.256		0.083	
MKT	0.159	1.134	*	1.518	**	1.908	***	0.574	
SMB	0.165	0.483	**	0.943	***	0.782	***		
HML	0.047	-0.284		-0.187		0.874	**		
RMW		0.322	*	0.009					
CMA		0.514	*	0.419					
UMD				3.170	**	4.158	***		
RMV								0.261	
RIA								0.163	*
ROP								0.183	*
Adjusted R^2	0.296	0.733		0.860		0.768		0.693	

In Table 3, the coefficients for MKT are all positive. It is significant in the Carhart four-factor model and the five-factor model with UMD factor (six-factor model), and less significant in the five-factor model. The coefficients of SMB are also positive for all models. It is significant in the six-factor model, the Carhart four-factor model, and less significant in the original five-factor model without the UMD factor. HML has negative coefficients in the five-factor model and the six-factor model. In Carhart-four factor model, however, HML is significant with positive coefficients. UMD is significant with positive coefficients in both the five-factor model and the six-factor model. Adding UMD factor to the original five-factor model results in increase in adjusted R-squared value to 0.860. The adjusted R-squared value of the Carhart four-factor, which drops RMW and CMA factor comparing to the five-factor model, increased only by 0.035. The coefficients of RMW and CMA are positive but only significant at 10% level in the five-factor model. RIA and ROP also have positive coefficients and are significant at 10% level in the empirical q-factor model. In the test results of P18, we can conclude that RMW, CMA, RIA, and ROP are not strong explanatory variables for Japan.

In Table 4, the regression test result for P20, most of the risk factors in each model have positive coefficients and are significant. The coefficients for MTK are negative in the three-factor model and the empirical q-factor model while it is significant with positive coefficients in six-factor model and Carhart four-factor model. SMB and HML are significant in all four models and the coefficients are positive. Different from the test results of P18, we find that RMW is significant in both the five-factor model and the six-factor model, with positive coefficients. UMD is significant with positive coefficients in both the six-factor model and the Carhart four-factor model. RMV, RIA, and ROP are all significant at 1% level with positive coefficients. In results for P20, adding or dropping factors does not have much influence on the adjusted R-squared values, and we can only conclude that CMA is not a significant explanatory variable comparing with other factors.

Table 4. Fama and MacBeth Regression Test Result for Test Portfolio P20 (01/1978–12/2018)

	Three-factor model		Five-factor model		Five-factor + UMD		Carhart 4-factor model		q-factor model	
Intercept	0.698	**	0.153		-0.705	*	-0.735	*	1.225	***
MKT	-0.208		0.885	*	2.816	***	3.011	***	-0.734	*
SMB	0.420	**	0.694	***	0.976	***	0.997	***		
HML	0.596	***	1.170	***	2.720	***	2.887	***		
RMW			0.989	***	0.550	**				
CMA			0.541	*	0.226					
UMD					5.101	***	6.828	***		
RMV									0.667	***
RIA									0.948	***
ROP									0.842	***
Adjusted R^2	0.656		0.747		0.795		0.762		0.681	

In Table 5, MKT again, has a negative coefficient for three-factor model and for the empirical q-factor model, however, it is significant in the six-factor model and the Carhart four-factor model, and the coefficients are positive. SMB and HML show the same level of significance with positive coefficients in all four models. RMW and CMA are significant at 1% level in the original five-factor model while MKT is not. However, MKT re-emerges as a strong explanatory variable in the Carhart four-factor model after dropping both RMW and CMA, and the adjusted R-squared values increased to 0.802. UMD is significant in both the six-factor model and the Carhart four-factor model and adding UMD to the original five-factor model increase the adjusted R-squared value of it to 0.823. RMV, RIA, and ROP are all significant with positive coefficients for the empirical q-factor model. The overall results of P45 are consistent with that of P20.

Table 5. Fama and MacBeth Regression Test Result for Test Portfolio P45 (01/1978–12/2018)

	Three-factor model	Five-factor model	Five-factor + UMD	Carhart 4-factor model	q-factor model
Intercept	1.109 ***	0.511 *	-0.359	-0.255	1.300 ***
MKT	-0.670 *	0.598	2.347 ***	2.276 ***	-0.767 *
SMB	0.412 **	0.772 ***	0.934 ***	0.998 ***	
HML	0.429 **	0.806 ***	2.670 ***	2.385 ***	
RMW		1.098 ***	0.172		
CMA		0.780 ***	-0.141		
UMD			5.836 ***	6.113 ***	
RMV					0.580 **
RIA					0.855 ***
ROP					0.782 ***
Adjusted R^2	0.654	0.720	0.823	0.802	0.713

According to the results from Table 3, 4, and 5, we can conclude that MKT, HML, SMB and UMD are strong explanatory variables for Japan while CMA is not. RMV, RIA, and ROP from the empirical q-factor model also show strong explanatory power. In test results of all three sets of portfolios, the five-factor model with UMD has the highest adjusted R-squared values. Adding UMD to the original five-factor model could result in substantial increase in adjusted R-squared values.

4.2 GMM test with Hansen-Jagannathan distance (1997)

The following equation is an example of GMM test on Fama and French (2015) five-factor model in which I test the Euler Condition (8) and we can judge the overall fitness of the model using Hansen and Jagannathan distance measure (Hansen and Jagannathan 1997). The observation period of test portfolios is from January 1978 to December 2018, and the test is conducted on all three sets of portfolios.

$$E\left[(r_{p,t} - r_{f,t}) \cdot \left(1 + \delta_1(r_{M,t} - r_{f,t}) + \delta_2 SMB_t + \delta_3 HML_t + \delta_4 RMW_t + \delta_5 CMA_t\right)\right] = 0 \quad (8)$$

Table 6 reports the GMM test results for P18. MKT is significant with the correct negative signs for all candidate models (Jagannathan and Wang 1996). SMB is significant except for the three-factor model. UMD is significant for both the six-factor model and the Carhart four-factor model. RIA and ROP are significant at 10% level for the empirical q-factor model. For the distance measures, we can see that the six-factor model has the shortest distance at 0.133, which is much smaller than that of the original five-factor model. The Hansen-Jagannathan distance (HJ-distance) for Carhart four-factor is 0.148, which is a little bit longer than that of the six-factor model. The three-factor model has the longest distance at 0.240.

Table 6. GMM test with H-J distance result for Test Portfolio P18 (01/1978–12/2018)

	Three-factor model	Five-factor model	Five-factor + UMD	Carhart 4-factor model	q-factor model
MKT	-1.760 *	-2.558 ***	-5.337 ***	-5.045 ***	-1.768 **
SMB	-1.460	-3.703 *	-8.849 ***	-6.882 ***	
HML	-1.963	2.450	-0.374	-8.097 *	
RMW		-5.518 **	1.066		
CMA		-8.360 *	-6.230		
UMD			-20.180 **	-19.492 ***	
RMV					-2.127
RIA					-4.125 *
ROP					-3.843 *
HJ-Distance	0.240 **	0.211 *	0.133	0.148	0.217 *

Table 7 reports the GMM test results for P20. MKT and HML are significant with negative signs. RMW is only significant for the five-factor model and UMD is significant for both the six-factor model and the Carhart four-factor model. RIA and ROP are significant at 1% level and 5% respectively. For distance measures, we can see that, again, six-factor model has the shortest HJ-distance at 0.276, which is shorter than that of the five-factor model. However, different from the result of P18, the empirical q-factor has the longest distance at 0.353. The difference between the distance of the five-factor model and that of the Carhart four-factor model is not substantial.

Table7. GMM test with H-J distance result for Test Portfolio P20 (01/1978–12/2018)

	Three-factor model		Five-factor model		Five factor+UMD		Carhart 4-factor model		*q-factor* model	
MKT	-2.062	**	-2.664	***	-3.740	***	-3.714	***	-1.607	*
SMB	0.959		-0.662		-1.200		-0.436			
HML	-9.396	***	-11.696	***	-17.224	***	-15.904	***		
RMW			-8.978	**	-5.729					
CMA			-2.280		0.378					
UMD					-8.096	**	-9.334	***		
RMV									-1.814	
RIA									-9.305	***
ROP									-6.456	**
HJ-Distance	0.318	***	0.296	***	0.276	***	0.289	***	0.353	***

Table 8 reports the GMM test results for P45. Again, MKT and HML are significant with correct signs in all candidate models. RMW is significant for the five-factor model and the UMD is significant for both the six-factor model and the Carhart four-factor model. For distance measures, we can see that again, six-factor model has the shortest HJ-distance at 0.320. However, different from the result of P18, the empirical *q*-factor has the longest distance at 0.397 . The difference between the distance of the five-factor model and that of the Carhart four-factor model is 0. 029. The overall results of P45 are consistent with that of P20. In summary, for the GMM test results, we can conclude that the six-factor model did a better job because of the shortest distance. MKT, HML, UMD, RIA and ROP are strong explanatory variables.

Table 8. GMM test with H-J distance result for Test Portfolio P45 (01/1978–12/2018)

	Three-factor model		Five-factor model		Five-factor + UMD		Carhart 4-factor model		*q*-factor model	
MKT	-1.983	**	-2.531	***	-3.459	***	-3.578	***	-1.572	*
SMB	-0.255		-1.671		-2.280		-1.950			
HML	-7.077	***	-8.549	***	-16.249	***	-13.440	***		
RMW			-7.537	**	-1.791					
CMA			-2.801		4.413					
UMD					-10.303	***	-9.320	***		
RMV									-2.490	
RIA									-6.668	***
ROP									-5.230	**
HJ-Distance	0.377	***	0.362	***	0.320		0.333		0.397	***

4.3 GRS test (Gibbons et al., 1989):

Gibbons et al. (1989) introduced Gibbons-Ross-Shanken test (GRS test) for testing the mean-variance efficiency of candidate asset pricing models. GRS test is an F-test. The observation period of test portfolios is from January 1978 to December 2018. I conducted the GRS test on all three sets of portfolios, however, since I computed the empirical q-factors RMV, RIA, and ROP using R18. Each of the q-factors must be a linear combination of columns in P18. In this case, the GRS test is not applicable for the empirical q-factor model using P18.

Table 9. GRS test result Panel A(P18), Panel B (P20), Panel C (P45) (01/1978–12/2018)

Panel A

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	q -factor model
Factors	MKT+SMB+HML	MKT+SMB+HML+RMW +CMA	MKT+SMB+HML+RM W+CMA+UMD	MKT+SMB+HML+UMD	MKT+RMV+RIA+ROP
GRS F-value	5.569	5.170	5.100	5.458	N/A
p-Value	0.000	0.000	0.000	0.000	

Panel B

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	q -factor model
Factors	MKT+SMB+HML	MKT+SMB+HML+RMW +CMA	MKT+SMB+HML+RM W+CMA+UMD	MKT+SMB+HML+UMD	MKT+RMV+RIA+ROP
GRS F-value	5.038	4.775	4.670	4.900	6.344
p-Value	0.000	0.000	0.000	0.000	0.000

Panel C

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	q -factor model
Factors	MKT+SMB+HML	MKT+SMB+HML+RMW +CMA	MKT+SMB+HML+RM W+CMA+UMD	MKT+SMB+HML+UMD	MKT+RMV+RIA+ROP
GRS F-value	2.914	2.771	2.704	2.834	3.301
p-Value	0.000	0.000	0.000	0.000	0.000

Table 9 shows the GRS test results for all three sets of portfolios. Panel A is the GRS test results of candidate models for P18, Panel B is the GRS test results of candidate models for P20, and Panel C is the GRS test results of candidate models for P45. We can see all candidate models are having F-values larger than 1 and p-values smaller than 0.05, thus, all candidate models are rejected. In Panel A, the F-value of the six-factor model at 5.100 indicates that it functions at a similar level as the five-factor level, which has a F-value at 5.170. The three-factor model and the Carhart four-factor model are at the similar level. In Panel B and Panel C, results are similar. In Panel B, the differences between F-values of candidate models indicate that the six-factor model and the original five-factor model function at a similar level, and the Carhart four-factor model and the three-factor model function at a similar level. The F-values of the empirical q-factor model indicate that the performance of it is inferior to that of other candidate models.

Considering the previous Fama-MacBeth test results and GMM test results, we can conclude that MKT, HML, UMD, RIA and ROP are strong explanatory variables while CMA is a redundant factor. The performance of Fama-French five-factor model with UMD and the Carhart four-factor model are better than those of the three-factor model, the original five-factor model, and the empirical *q*-factor model in explaining Japanese market data.

5. Robustness Checks

As I mentioned in Section 3, I divided the whole observation period into three characteristic sub-period for comparative purposes. The first subperiod is from the starting point, January 1978, to December 1989. During the first subperiod, there was a stock market bubble in Japan. Stock market prices and real estate inflated greatly. This subperiod includes the economic bubble period. In December 1989, the stock market bubble burst. The second subperiod is from January 1990 to December 2009. The economic stagnation in Japan was serious after the bubble burst, which brought huge influence on Japanese economy. This subperiod includes the period known as the Lost two decades. The third subperiod starts from January 2010 to December 2018. This period includes the time Japan entered the High Frequency Trading era because in January 4, 2010, the new trading system *arrowhead* was launched. By dividing the observation period into three parts, we can see the how the explanatory power of each candidate model changes through time more directly. In this section, I will be focusing on the test results from the third subperiod.

5.1 Stock Market Bubble – Subperiod 1

Table A7 shows the Fama-MacBeth regression test results for all three sets of portfolios in the first subperiod in separate panels. In Panel A, MKT is significant at 1% level with positive coefficient in the three-factor model, and it is significant at 5% level in the Carhart four-factor model and is significant at 10% level in the five-factor model. SMB is significant with positive coefficients except for the empirical *q*-factor model. HML is not significant except for the three-factor model. RMV and RIA are significant for the empirical *q*-factor model. Adding UMD factor to the original five-factor model barely increase the adjusted R-squared value while adding the CMA and RMW to the three-factor model increase the adjusted R-squared value by 0.213. In Panel B, MKT is significant with positive coefficients except for the empirical q-factor model. SMB is significant with positive coefficients for all candidate models. HML is significant for the three-factor model and the Carhart four-factor model. RMW is significant for both the five-factor model and the six-factor model. CMA is only significant in the original five-factor model. For P20, also, adding the RMW and CMA to the three-factor model increases the adjusted R-squared value while adding the UMD to the five-factor model, the adjusted R-squared value remains the same. In Panel C, factor returns show positive coefficients and is positive for most of the time, except for RMW and CMA in the six-factor model, UMD in the Carhart four-factor model, and MKT in the empirical q-factor model. Adding UMD to the five-factor model increases the adjusted R-squared value by 0.02.

Table A8 reports the GMM test results with HJ-distance for three sets of portfolios in the first subperiod in separate panels. In all three panels, RMW, CMA, UMD and ROP are not strong explanatory variables. The distance measures in all three panels show that the five-factor model with UMD factor has the shortest distance. However, adding UMD factor to the original five-factor model only shorten the distance by 0.004 in average. The empirical q-factor model has the longest distance in test results. Dropping RMW and CMA results in increase in the HJ-distance by 0.011 in average. The differences between the distance measures of candidate models are not substantial.

Table 10 shows the GRS test results for all three sets of portfolios in the first subperiod. Panel A is the GRS test results of candidate models for P18, Panel B is the GRS test results of candidate models for P20, and Panel C is the GRS test results of candidate models for P45. Different from the GRS test results of the whole sample period, the six-factor model now has the biggest F-value. The results are obvious, F-values of all candidate models are bigger than 1. In Panel A, the three-factor model has the smallest F-value at 4.710. In Panel B, the Carhart four-factor model has the smallest F-value at 7.685. In Panel C, the empirical q-factor model has the smallest F-value at 3.900.

Table 10. GRS test result Panel A(P18), Panel B (P20), Panel C (P45) (01/1978–12/1989)

Panel A

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	*q* -factor model
Factors	MKT+SMB+HML	MKT+SMB+HML+RMW+CMA	MKT+SMB+HML+RMW+CMA+UMD	MKT+SMB+HML+UMD	MKT+RMV+RIA+ROP
GRS F-value	4.710	5.077	5.099	4.780	N/A
p-Value	0.000	0.000	0.000	0.000	

Panel B

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	*q* -factor model
Factors	MKT+SMB+HML	MKT+SMB+HML+RMW+CMA	MKT+SMB+HML+RMW+CMA+UMD	MKT+SMB+HML+UMD	MKT+RMV+RIA+ROP
GRS F-value	7.701	9.384	9.661	7.685	9.271
p-Value	0.000	0.000	0.000	0.000	0.000

Panel C

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	*q* -factor model
Factors	MKT+SMB+HML	MKT+SMB+HML+RMW+CMA	MKT+SMB+HML+RMW+CMA+UMD	MKT+SMB+HML+UMD	MKT+RMV+RIA+ROP
GRS F-value	4.609	5.295	5.416	4.659	3.900
p-Value	0.000	0.000	0.000	0.000	0.000

From the tests results of the first period, we can conclude UMD is not a significant explanatory variable for Japan during the first subperiod. SMB, HML, MKT, RMV and RIA are strong explanatory variables. However, because of the economic bubble and increasing stock prices, it is difficult to conclude which candidate model did better in explaining Japanese market during this period. Moreover, according to the test results, the adjusted R-squared values and the HJ-distance measures of candidate models show little difference.

5.2 Lost Two Decades– Subperiod 2

Table A9 reports the Fama-MacBeth regression test results for P18, P20, and P45 in the second subperiod in separate panels. In Panel A, Only HML has negative coefficients in the five-factor model and the six-factor model. None of the factors is significant and all candidate models show low adjusted R-squared values. In Panel B, MKT is significant with positive coefficient only for the Carhart four-factor model. SMB has negative coefficients for four candidate models. HML, on the other hand, has positive coefficients for all four candidate models and is significant at 1% level except for the three-factor model. UMD is significant at 10% level for the six-factor model and at 1% level for the Carhart four-factor model. Adding the UMD to the original five-factor model increases the adjusted R-squared value to 0.906. In panel C, MKT is not significant except for the Carhart four-factor model. HML is significant with positive coefficients in four candidate models. UMD also show positive coefficients and it is significant in both the six-factor model and the Carhart four-factor model.

Thus, we can conclude that only UMD and HML are strong explanatory variables for the second subperiod.

Table A10 reports the GMM test with HJ-distance results for P18, P20, and P45 in the second subperiod in separate panels. In Panel A, the six-factor model shows the shortest distance at 0.291, which is lower than that of the original five-factor model. None of the factors is significant. In the rest of the panels, the six-factor model also has the shortest distance. In average, adding UMD to the original five-factor model can shorten the distance by 0.039. HML is significant with correct negative signs in all candidate models. CMA is significant in both models but with positive coefficients. UMD is also a strong explanatory variable.

Table 11 shows the GRS test results for all three sets of portfolios in the first subperiod in separate panels. In Panel A and B, from test results for P18 and P20, all candidate models have F-values bigger than 1 and p-values smaller than 0.05. In Panel C, although the three-factor model and the five-factor model have F-values bigger than 1, the p-values of which are 0.065 and 0.080 respectively. Thus, we could not reject these two candidate models. Also, since the five-factor model has a smaller F-value, it is a better model in explaining Japanese market than the three-factor model. The six-factor model has an F-value at 1.441 and p-value at 0.048, which is close to 0.05.

Table 11. GRS test result Panel A(P18), Panel B (P20), Panel C (P45) (01/1990–12/2009)

Panel A	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	q-factor model
Factors	MKT+SMB+HML	MKT+SMB+HML+RMW+CMA	MKT+SMB+HML+RMW+CMA+UMD	MKT+SMB+HML+UMD	MKT+RMV+RIA+ROP
GRS F-value	2.364	2.315	2.332	2.371	N/A
p-Value	0.002	0.002	0.002	0.002	
Panel B	**Three-factor model**	**Five-factor model**	**Five factor+UMD**	**Carhart 4-factor model**	**q-factor model**
Factors	MKT+SMB+HML	MKT+SMB+HML+RMW+CMA	MKT+SMB+HML+RMW+CMA+UMD	MKT+SMB+HML+UMD	MKT+RMV+RIA+ROP
GRS F-value	2.542	2.505	2.559	2.595	2.953
p-Value	0.000	0.001	0.000	0.000	0.000
Panel C	**Three-factor model**	**Five-factor model**	**Five factor+UMD**	**Carhart 4-factor model**	**q-factor model**
Factors	MKT+SMB+HML	MKT+SMB+HML+RMW+CMA	MKT+SMB+HML+RMW+CMA+UMD	MKT+SMB+HML+UMD	MKT+RMV+RIA+ROP
GRS F-value	1.394	1.363	1.441	1.465	1.517
p-Value	0.065	0.080	0.048	0.041	0.029

From the test results for the second subperiod, we can conclude that HML and UMD are strong explanatory variables for Japan during this period while CMA, SMB and the empirical q factors are not. Thus, we can conclude that the performance of the empirical q-factor model is inferior to that of the six-factor model and that of the original five-factor model in explaining Japanese market in this subperiod.

5.3 High Frequency Trading Era – Subperiod 3

5.3.1 Fama-MacBeth Regression (1973)

Table 12 reports the Fama-MacBeth regression test result for P18 in the last subperiod. Only MKT and SMB are significant with positive coefficients for the five-factor model. In the empirical *q*-factor model, RMW and ROP are significant with positive coefficients. The differences between the adjusted R-squared values of candidate factors are not substantial since adding UMD to the original five-factor model or dropping RMW and CMA does not affect the values much.

Table 12. Fama and MacBeth Regression Test Result for Test Portfolio P18 (01/2010–12/2018)

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	*q-factor* model
Intercept	0.933	-0.143	-0.256	0.249	-0.060
MKT	0.434	2.203 *	1.825	0.976	1.535
SMB	0.456	0.791 **	0.539	0.306	
HML	-0.422	-0.305	0.183	0.096	
RMW		0.347	0.246		
CMA		0.405	0.201		
UMD			0.996	1.331	
RMV					0.538 **
RIA					0.118
ROP					0.278 *
Adjusted *R2*	0.596	0.663	0.688	0.670	0.676

Table 13 reports the Fama-MacBeth regression test result for P20 in the last subperiod. SMB is significant at 1% level for the three-factor model and the Carhart four-factor model, also, the coefficients are positive. The coefficients of HML are all positive while it is significant only for the five-factor model and the six-factor model. RMW and CMA are both significant for the five-factor model and the six-factor model while the coefficients of CMA are all negative. For the empirical *q*-factor model, only RMV is significant with positive coefficient. Adding UMD to the five-factor model does not improve the adjusted R-squared value of the six-factor model. From the results, we can also know that adding RMW and CMA to the three-factor model affects the significance of SMB since SMB is only significant in candidate models without RMW and CMA.

Table 13. Fama and MacBeth Regression Test Result for Test Portfolio P20 (01/2010–12/2018)

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	*q-factor* model
Intercept	0.322	0.362	0.368	0.377	0.286
MKT	0.912	-1.816	-1.821	0.805	1.248
SMB	1.125 ***	0.251	0.241	1.050 ***	
HML	0.264	3.041 ***	3.055 ***	0.336	
RMW		0.853 **	0.859 **		
CMA		-1.258 **	-1.250 **		
UMD			0.046	0.217	
RMV					0.972 **
RIA					0.141
ROP					0.239
Adjusted *R2*	0.603	0.803	0.801	0.599	0.606

Table 14 reports the Fama-MacBeth regression test result for P45 in the last subperiod. MKT is not significant except for the six-factor model and the coefficient is negative. SMB is only significant for the three-factor model and the coefficient is positive. HML is significant with positive coefficients except for the three-factor model. RMW is significant with positive coefficients in both the five-factor model and the six-factor model while CMA is significant with negative coefficients. UMD has positive coefficients and it is significant at 5% level in both the six-factor model and the Carhart four-factor model. For the empirical *q*-factor model, only RMV and ROP is significant and the coefficients are positive. From the adjusted R-squared values, we can see that adding RMW and CMA increases the adjusted value to 0.783. However, since the coefficients of CMA have negative signs, we can conclude that CMA is not a strong explanatory variable for Japan during this period. Also, considering the results from Table 12 and Table 13, UMD is also not a strong explanatory variable during this period. HML, SMB and RMW show certain level of significance.

Table 14. Fama and MacBeth Regression Test Result for Test Portfolio P45 (01/2010–12/2018)

	Three-factor model		Five-factor model		Five factor+UMD		Carhart 4-factor model		*q-factor* model	
Intercept	0.390		0.754		1.216	**	0.785		0.501	
MKT	0.886		-1.490		-2.752	**	-0.082		1.240	
SMB	1.207	***	0.439		-0.378		0.525			
HML	0.141		2.282	***	3.290	***	1.002	*		
RMW			0.759	**	0.731	**				
CMA			-0.923	**	-1.023	**				
UMD					2.406	**	2.214	**		
RMV									1.030	***
RIA									0.290	
ROP									0.490	**
Adjusted *R2*	0.649		0.783		0.830		0.687		0.686	

5.3.2 GMM test with Hansen-Jagannathan distance (1997)

Table 15 reports the GMM test with HJ-distance results of P18 for the third subperiod. We can see that SMB is significant with correct negative signs in all candidate models. MKT is significant except for the six-factor model. Judging from the distance measures, the empirical q-factor model has the shortest distance at 0.428. The five-factor model and the six-factor model have the same distance at 0.439. Therefore, we can conclude that adding the UMD does not improve the overall fitness of the model. The small difference between the HJ-distance of the three-factor model and that of the Carhart four-factor model also indicates that UMD is a redundant factor. RMV and ROP are significant for the empirical q-factor model with negative signs.

Table 15. GMM test with H-J distance result for Test Portfolio P18 (01/2010–12/2018)

	Three-factor model		Five-factor model		Five factor+UMD		Carhart 4-factor model		*q-factor* model	
MKT	-5.318	**	-5.854	**	-5.544		-4.992	**	-5.642	***
SMB	-10.075	**	-11.190	***	-10.462	*	-8.628	*		
HML	2.489		-1.194		-2.539		-0.107			
RMW			-12.060		-11.600					
CMA			-5.433		-4.296					
UMD					-1.874		-4.555			
RMV									-11.288	***
RIA									-5.106	
ROP									-12.368	**
HJ-Distance	0.458	*	0.439	**	0.439	**	0.455	*	0.428	*

Table 16 reports the GMM test with HJ-distance results of P20 for the third subperiod. MKT is significant with negative signs except for the five-factor model. SMB is significant for all candidate models. RMW, ROP and RMV are also strong explanatory variables. The six-factor model has the shortest distance at 0.387, which is much smaller than that of the original five-factor model. The three-factor model has the longest distance at 0.516.

Table 16. GMM test with H-J distance result for Test Portfolio P20 (01/2010–12/2018)

	Three-factor model		Five-factor model		Five factor+UMD		Carhart 4-factor model		*q-factor* model	
MKT	-4.748	**	-3.966		-4.777		-5.861	**	-6.105	***
SMB	-9.965	**	-11.666	**	-15.963	**	-14.283	***		
HML	-2.550		-21.065	***	-13.164		5.849			
RMW			-39.880	***	-40.272	***				
CMA			-3.676		-1.340					
UMD					17.428	*	16.251	*		
RMV									-11.468	**
RIA									1.680	
ROP									-18.315	**
HJ-Distance	0.516	**	0.432		0.387		0.484		0.478	**

Table 17 reports the GMM test with HJ-distance results of P45 for the third subperiod. The empirical q-factor model has the shortest distance at 0.652, and differences between the HJ-distance of the five-factor model and that of the six-factor model is not substantial. In all of the three tables, SMB, RMV and ROP are significant while CMA is not. Thus, we can conclude that CMA is not a strong explanatory variable during this subperiod.

Table 17. GMM test with H-J distance result for Test Portfolio P20 (01/2010–12/2018)

	Three-factor model		Five-factor model		Five factor+UMD		Carhart 4-factor model		*q-factor* model	
MKT	-4.758	**	-6.206	**	-5.770	**	-4.465	**	-5.894	***
SMB	-12.033	***	-13.977	***	-12.839	**	-10.895	**		
HML	-2.306		-4.837		-6.979		-4.415			
RMW			-16.531	*	-16.416	*				
CMA			-10.827		-9.520					
UMD					-2.869		-3.415			
RMV									-13.036	***
RIA									-6.887	
ROP									-13.582	*
HJ-Distance	0.678	*	0.658	*	0.657	*	0.676	*	0.652	

5.3.3 GRS test (Gibbons et al., 1989)

Table 18 reports the GRS test results of P18, P20, and P45 for the third subperiod in three panels separately. In all of the three panels, all candidate models have F-values larger than 1. However, in Panel A, each of the candidate models has a p-value bigger than 0.05. Therefore, we could not reject any of the candidate models. In Panel B, however, p-values are smaller than 0.05. All candidate models are rejected. In Panel C, the empirical q-factor model has the smallest F-value and a p-value at 0.083, which is bigger than 0.05.

Table 18. GRS test result Panel A(P18), Panel B (P20), Panel C (P45) (01/2010–12/2018)

Panel A					
	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	q -factor model
Factors	MKT+SMB+HML	MKT+SMB+HML+RMW+CMA	MKT+SMB+HML+RMW+CMA+UMD	MKT+SMB+HML+UMD	MKT+RMV+RIA+ROP
GRS F-value	1.716	1.582	1.559	1.699	N/A
p-Value	0.051	0.083	0.091	0.055	
Panel B					
	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	q -factor model
Factors	MKT+SMB+HML	MKT+SMB+HML+RMW+CMA	MKT+SMB+HML+RMW+CMA+UMD	MKT+SMB+HML+UMD	MKT+RMV+RIA+ROP
GRS F-value	1.965	1.758	1.786	1.993	1.940
p-Value	0.017	0.040	0.036	0.016	0.019
Panel C					
	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	q -factor model
Factors	MKT+SMB+HML	MKT+SMB+HML+RMW+CMA	MKT+SMB+HML+RMW+CMA+UMD	MKT+SMB+HML+UMD	MKT+RMV+RIA+ROP
GRS F-value	1.603	1.491	1.585	1.643	1.468
p-Value	0.044	0.076	0.050	0.037	0.083

From the test results, we can conclude that, for the third subperiod, UMD and CMA are redundant factors for Japan during this period. For the third subperiod, the empirical q-factor model and the original five-factor model did better in explaining the Japanese data.

6. Conclusion and Future Research

I test recent asset pricing models and investigate which one of the five candidate models explains well the data for Japan. For the entire sample period, we can conclude that HML, SMB and UMD are strong explanatory variables for Japan while CMA is not, which is consistent with the conclusion in Fama and French (2017)'s conclusion that CMA is a redundant factor for Japan. In test results of all three sets of portfolios, the five-factor model with UMD has the highest adjusted R-squared values. Adding UMD to the original five-factor model could result in substantial increase in adjusted R-squared values. The Fama-French five-factor model with UMD does a better job in explaining the Japanese market than other candidate models. Unfortunately, all candidate models are rejected in the GRS tests. Overall, the six-factor model and the Carhart four-factor model are better than the rest of the candidate models in explaining Japanese market. For phase 1, the stock market bubble period, MKT, SMB and HML are strong explanatory variables for Japan while UMD is redundant. RMV and RIA are important, but the HJ-distance of the empirical *q*-factor model is long. Overall, it is difficult to conclude that which candidate model did better since the adjusted R-squared values and the HJ-distance measures show little difference between each candidate models. For phase 2, the lost two decades, HML and UMD are strong explanatory variables for Japan while CMA, SMB and the empirical *q* factors are redundant. Overall, the six-factor model and the original five-factor model have stronger explanatory power. For Phase 3, the high frequency trading era, the five-factor model and the empirical *q*-factor model seem to do a better job in explaining Japanese market. SMB, HML and RMW in the five-factor model are strong explanatory variables. Also, RMV and ROP in the empirical *q*-factor model also show strong explanatory power. UMD and CMA are redundant factors.

In conclusion, the six-factor model and the Carhart four-factor model did better than other candidate models during the sampling period from January 1978 to December 2018. In the first subperiod, it is difficult However, in the third sub-period, the five-factor model and the empirical *q*-factor model seem to do a better job in explaining Japanese market than other candidate models.

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APPENDIX

Table A1. Descriptive statistics of each factor

Subperiod 1: 1978.1-1989.12

Factors	**Mean**	**S.D**	**25%ile**	**Median**	**75%ile**
MKT	1.132	3.828	-0.997	1.001	2.853
SMB	0.240	3.904	-1.508	0.730	2.758
HML	0.589	3.114	-1.523	0.181	2.337
RMW	0.114	2.726	-1.399	0.011	1.460
CMA	0.269	2.574	-1.345	0.266	1.770
UMD	0.206	4.343	-2.147	0.752	2.988
RMV	0.245	3.596	-1.514	0.608	2.051
RIA	0.363	2.368	-1.137	-0.063	1.497
ROP	0.250	2.449	-1.194	0.004	1.613

Subperiod 2: 1990.1-2009.12

Factors	**Mean**	**S.D**	**25%ile**	**Median**	**75%ile**
MKT	-0.323	5.775	-3.889	-0.393	3.652
SMB	-0.041	3.343	-2.189	-0.063	2.047
HML	0.573	2.967	-0.803	0.694	2.139
RMW	-0.078	2.273	-1.323	-0.128	1.182
CMA	0.072	2.541	-0.934	0.177	1.373
UMD	-0.253	5.086	-2.206	0.200	2.567
RMV	0.051	3.580	-2.032	0.047	1.989
RIA	0.109	2.097	-1.093	0.144	1.354
ROP	-0.051	1.960	-1.127	-0.070	1.117

Subperioed 3: 2010.1-2018.12

Factors	**Mean**	**S.D**	**25%ile**	**Median**	**75%ile**
MKT	0.788	4.786	-1.390	0.742	3.789
SMB	0.362	2.340	-1.108	0.213	2.201
HML	0.094	2.439	-1.462	-0.142	1.496
RMW	0.153	1.483	-0.709	0.225	1.045
CMA	-0.118	1.461	-1.242	-0.095	0.889
UMD	0.099	2.882	-1.320	0.324	1.691
RMV	0.348	2.047	-0.932	0.162	1.848
RIA	0.083	1.430	-0.840	0.040	0.931
ROP	0.174	1.388	-0.668	0.246	1.067

Table A2. Correlation matrix between factors

Subperiod 1: 1978.1-1989.12

	MKT	SMB	HML	RMW	CMA	UMD	RMV	RIA	ROP
MKT	1.000	-0.457	-0.393	0.380	-0.277	0.370	-0.471	-0.096	0.364
SMB	0.000	1.000	0.165	-0.344	0.097	-0.352	0.963	0.012	-0.366
HML	0.000	0.041	1.000	-0.391	0.492	-0.339	0.287	0.338	-0.330
RMW	0.000	0.003	0.000	1.000	-0.580	0.121	-0.328	-0.354	0.942
CMA	0.004	0.238	0.000	0.000	1.000	0.125	0.100	0.854	-0.388
UMD	0.000	0.000	0.000	0.595	0.203	1.000	-0.401	0.226	0.179
RMV	0.000	0.000	0.003	0.015	0.338	0.000	1.000	0.001	-0.365
RIA	0.099	0.407	0.003	0.000	0.000	0.096	0.617	1.000	-0.097
ROP	0.001	0.001	0.004	0.000	0.000	0.359	0.006	0.182	1.000

Subperiod 2: 1990.1-2009.12

	MKT	SMB	HML	RMW	CMA	UMD	RMV	RIA	ROP
MKT	1.000	0.118	-0.225	-0.197	-0.245	-0.322	0.021	0.058	-0.232
SMB	0.029	1.000	0.181	-0.286	-0.014	-0.173	0.926	0.224	-0.262
HML	0.000	0.085	1.000	-0.408	0.388	-0.310	0.438	0.361	-0.336
RMW	0.005	0.001	0.000	1.000	-0.445	0.273	-0.275	-0.471	0.948
CMA	0.000	0.180	0.000	0.000	1.000	-0.156	0.075	0.623	-0.262
UMD	0.000	0.158	0.009	0.002	0.055	1.000	-0.213	-0.275	0.238
RMV	0.421	0.000	0.000	0.001	0.849	0.233	1.000	0.286	-0.236
RIA	0.521	0.005	0.000	0.000	0.000	0.003	0.003	1.000	-0.228
ROP	0.004	0.000	0.000	0.000	0.000	0.003	0.002	0.000	1.000

Subperioed 3: 2010.1-2018.12

	MKT	SMB	HML	RMW	CMA	UMD	RMV	RIA	ROP
MKT	1.000	-0.336	0.320	-0.162	-0.262	-0.115	-0.302	-0.086	-0.248
SMB	0.001	1.000	-0.406	0.130	-0.205	0.413	0.929	-0.035	0.098
HML	0.001	0.001	1.000	-0.544	0.450	-0.558	-0.102	0.252	-0.440
RMW	0.083	0.202	0.000	1.000	-0.483	0.334	0.042	-0.296	0.921
CMA	0.017	0.041	0.000	0.000	1.000	-0.260	-0.095	0.596	-0.235
UMD	0.531	0.000	0.000	0.001	0.002	1.000	0.245	0.073	0.295
RMV	0.010	0.000	0.655	0.715	0.477	0.039	1.000	-0.017	0.025
RIA	0.544	0.563	0.008	0.005	0.000	0.953	0.766	1.000	0.034
ROP	0.012	0.248	0.000	0.000	0.014	0.003	0.778	0.504	1.000

Table A3. Fama and MacBeth Regression Test Result for Test Portfolio P18, P20, P45

(01/1978–12/1989)

Panel A

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	q-factor model
Intercept	-0.530	0.517	0.566	0.096	0.899 *
MKT	3.626 ***	1.835 *	1.645	2.169 **	1.077
SMB	1.427 **	1.180 **	1.294 **	1.723 ***	
HML	1.649 **	0.288	0.435	0.792	
RMW		0.435	0.399		
CMA		0.643	0.457		
UMD			0.655	1.808	
RMV					0.859 *
RIA					0.441 **
ROP					0.265
Adjusted R^2	0.487	0.700	0.704	0.640	0.734

Panel B

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	q-factor model
Intercept	-1.263	0.405	0.599	-0.608	1.842 **
MKT	4.755 ***	2.177 **	2.039 *	3.568 ***	-0.322
SMB	2.679 ***	1.909 ***	1.643 **	2.494 ***	
HML	1.842 ***	0.797	0.431	1.684 ***	
RMW		0.996 **	1.169 **		
CMA		1.058 **	1.423		
UMD			-0.977	1.279	
RMV					1.008
RIA					0.989 ***
ROP					0.845 **
Adjusted R^2	0.748	0.796	0.796	0.768	0.767

Panel C

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	q-factor model
Intercept	-1.126	-0.259	-0.464	-0.549	1.227 *
MKT	4.477 ***	3.138 ***	2.983 ***	3.366 ***	0.584
SMB	2.629 ***	2.297 ***	2.867 ***	2.554 ***	
HML	1.645 ***	1.021 **	1.884 ***	1.477 ***	
RMW		0.782 **	0.318		
CMA		0.755 **	-0.228		
UMD			2.894 **	1.447	
RMV					1.360 **
RIA					0.851 ***
ROP					0.694 **
Adjusted R^2	0.781	0.808	0.828	0.806	0.771

Table A4. GMM test with H-J distance result for Test Portfolio P45 (01/1978–12/1989)

Panel A

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	*q* -factor model
MKT	-11.835 ***	-11.413 ***	-10.858 ***	-10.955 ***	-9.794 ***
SMB	-4.394 **	-5.458 **	-6.045 **	-5.642 **	
HML	-11.112 ***	-9.152 **	-10.250 **	-10.955 ***	
RMW		-5.042	-4.794		
CMA		-5.556	-3.921		
UMD			-2.315	-3.673	
RMV					-7.115 ***
RIA					-7.233 ***
ROP					-2.459
HJ-Distance	0.323	0.304	0.303	0.317	0.342

Panel B

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	*q* -factor model
MKT	-12.014 ***	-11.548 ***	-12.177 ***	-11.581 ***	-9.793 ***
SMB	-4.820 ***	-5.892 ***	-5.302 **	-5.340 ***	
HML	-10.385 ***	-9.058 ***	-7.195 *	-11.019 ***	
RMW		-6.358	-7.094 *		
CMA		-6.789	-9.522		
UMD			2.799	-1.995	
RMV					-7.708 ***
RIA					-9.633 ***
ROP					-3.817
HJ-Distance	0.364 **	0.345 **	0.343 **	0.362 **	0.400 **

Panel C

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	*q* -factor model
MKT	-11.955 ***	-11.471 ***	-10.541 ***	-11.261 ***	-9.692 ***
SMB	-5.417 ***	-6.241 ***	-7.152 ***	-6.286 ***	
HML	-10.324 ***	-9.958 ***	-12.418 ***	-11.286 ***	
RMW		-5.014	-4.257		
CMA		-3.927	-0.197		
UMD			-3.857	-3.204	
RMV					-8.194 ***
RIA					-7.646 ***
ROP					-3.120
HJ-Distance	0.459	0.449	0.441	0.451	0.502

Table A5. Fama and MacBeth Regression Test Result for Test Portfolio P18, P20, P45 (01/1990–12/2009)

Panel A

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	*q* -factor model
Intercept	-0.452	-0.696	-1.036	-0.455	-0.487
MKT	0.336	0.494	1.689	0.373	0.335
SMB	0.002	0.265	0.270	0.000	
HML	0.092	-0.464	-0.057	0.113	
RMW		0.009	0.115		
CMA		0.305	0.465		
UMD			1.392	0.063	
RMV					0.013
RIA					0.083
ROP					0.016
Adjusted R^2	0.107	0.229	0.292	0.103	0.173

Panel B

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	*q* -factor model
Intercept	0.392	0.574	-0.129	-0.692 *	0.777 **
MKT	-0.519	-1.090	0.937	2.584 ***	-1.217 **
SMB	-0.018	-0.747 **	-0.640 **	-0.086	
HML	0.686 *	1.586 ***	2.391 ***	2.277 ***	
RMW		-0.504	-0.295		
CMA		-1.326 ***	-1.009 *		
UMD			2.239 *	4.001 ***	
RMV					0.222
RIA					0.454
ROP					0.154
Adjusted R^2	0.708	0.885	0.906	0.787	0.540

Panel C

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	*q* -factor model
Intercept	0.488	0.477	-0.217	-0.445	0.728 *
MKT	-0.553	-0.553	1.582	2.313 **	-1.003 *
SMB	-0.080	-0.501	-0.401	-0.094	
HML	0.603 *	1.343 ***	2.271 ***	2.107 ***	
RMW		-0.075	0.027		
CMA		-0.690	-0.471		
UMD			2.745 **	3.933 ***	
RMV					0.041
RIA					0.468 *
ROP					0.162
Adjusted R^2	0.609	0.716	0.748	0.684	0.487

Table A6. GMM test with H-J distance result for Test Portfolio P45 (01/1990–12/2009)

Panel A

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	*q* -factor model
MKT	0.675	0.951	-2.258	-2.379	0.962
SMB	-0.312	-0.847	-1.868	-0.718	
HML	-1.356	0.960	-3.484	-7.304	
RMW		1.383	2.234		
CMA		-1.097	-2.561		
UMD			-9.278	-8.366	
RMV					0.156
RIA					-2.381
ROP					1.469
HJ-Distance	0.321 *	0.320 **	0.291	0.297	0.317 **

Panel B

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	*q* -factor model
MKT	-0.722	0.429	-2.222	-3.461 **	1.140
SMB	4.807 **	6.307 **	6.634 **	5.128 **	
HML	-12.539 ***	-15.415 ***	-22.107 ***	-19.618 ***	
RMW		4.699	5.037		
CMA		11.803 **	11.605 *		
UMD			-7.028 **	-7.187 **	
RMV					1.753
RIA					-5.232
ROP					3.038
HJ-Distance	0.349 *	0.319	0.272	0.304	0.432 ***

Panel C

	Three-factor model	Five-factor model	Five factor+UMD	Carhart 4-factor model	*q* -factor model
MKT	-0.404	0.400	-1.830	-2.720 *	1.145
SMB	3.254	4.182 *	4.330	3.116	
HML	-8.786 ***	-10.330 ***	-16.413 ***	-14.488 ***	
RMW		3.269	4.891		
CMA		7.709 *	9.257 *		
UMD			-6.859 **	-6.370 **	
RMV					1.108
RIA					-1.596
ROP					4.027
HJ-Distance	0.445	0.431	0.391	0.412	0.494 **